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ATMOSPHERIC IONIZATION NEAR THE GROUND DURING THUNDERSTORMS

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The effects described in this paper were observed while investigating the diurnal variation of small-ion formation

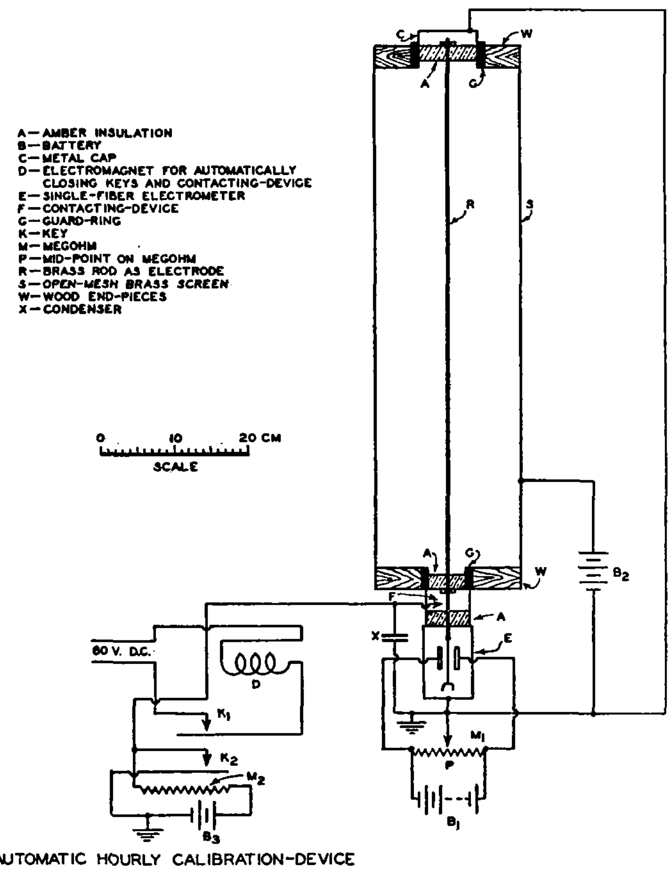

FIGURE 1.—Device for measuring total ionization in atmosphere.

in the lower atmosphere. The observing station was on the grounds of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, situated in the more sparsely settled portion of the northwestern section of the District of Columbia.

The apparatus used is diagrammatically shown in figure 1. Ions are formed inside an airtight chamber by radiations which penetrate its wall. The chamber consists of a brass screen in the form of a cylinder, covered with thin cellophane. An electric field, maintained between an insulated concentric brass rod and the screen, causes the collection of ions of one sign on the rod. An electrometer connected to the rod measures the accumulated charge, thus indicating the rate at which the ions are formed inside the cylinder. The accumulation of charge is allowed to continue for 54 minutes, after which the rod is discharged, the electrometer calibrated, and the accumulation of charge resumed at the end of 60 minutes, the entire process being automatic. The deflections of the electrometer, directly proportional to the ionization, are recorded on photographic paper attached to a rotating drum. A reproduction of the record for one 24-hour interval, during which a thunderstorm occurred, is shown in figure 2*a*, in which the deflection at 8 hours corresponds to the production of 6.5 pairs of ions per second per cubic centimeter. A copy of the rain record for the same interval is shown in figure 2*b*.

In addition to diurnal and sporadic variations in the rate of ion formation in the closed vessel, a large increase in the rate of formation was observed to occur during thunderstorms and the few hours following them. This phenomenon is evidenced by figures 3*a* and 3*b*, showing the rainfall during half-hour intervals and the average increased rate of ion formation over corresponding hour intervals for several days during June to August 1933; the base values for the ionization are the mean ionization rates for the 3-hour interval preceding the rain. The salient features shown by figures 3*a* and 3*b* are: (1) The ionization increases as soon as the rain has begun to fall; (2) the effect persists for several hours after the rain has ceased; and (3) the effect is roughly proportional to the amount of rain which has fallen. During the heavy rain associated with the hurricane which occurred at Washington during the latter part of August, no appreciable increase in the rate of ion formation occurred, at least not before the heavy winds damaged the apparatus. It may be remarked that, during the period of recording, no thunderstorm occurred without abnormally high ionization; the ionization was abnormally high only once when there was no thunderstorm and in this case there was a heavy fog.

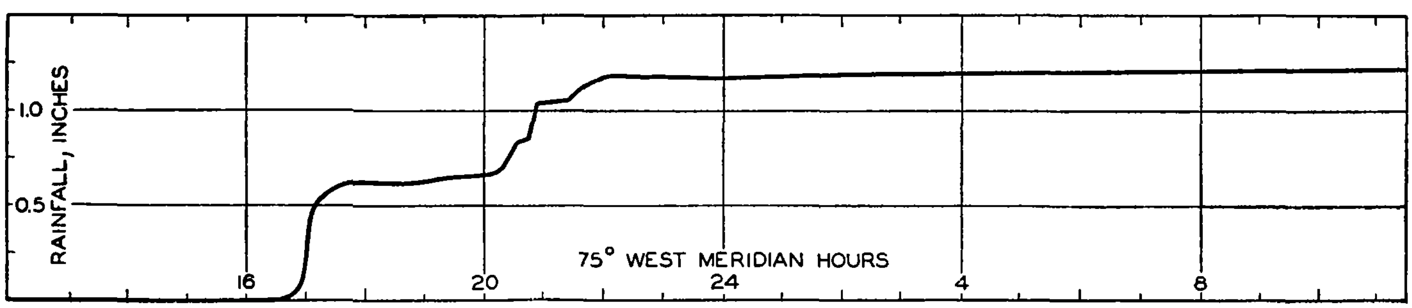

FIGURE 2*b*. Rainfall, Department of Terrestrial Magnetism, laboratory grounds, Washington, D.C., June 25–26, 1933.

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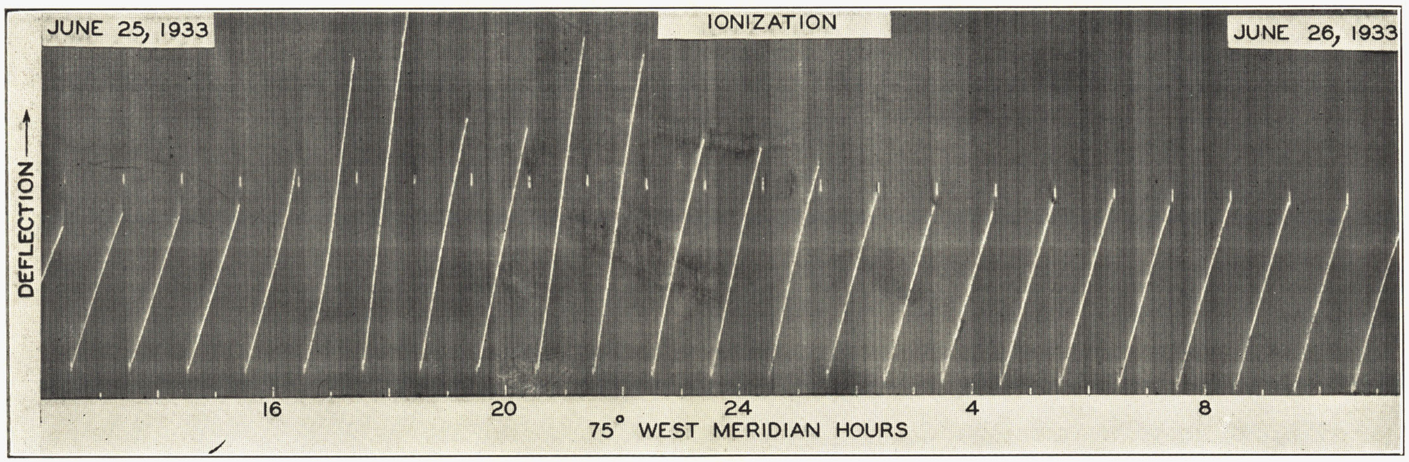

FIGURE 2a.—Ionization record, Washington, D.C., June 25–26, 1933.

In figure 4 the total rainfall during each storm is coordinated with the accumulated excess of ion formation during that storm. The degree of the proportionality is quite fair, particularly when consideration is given to the

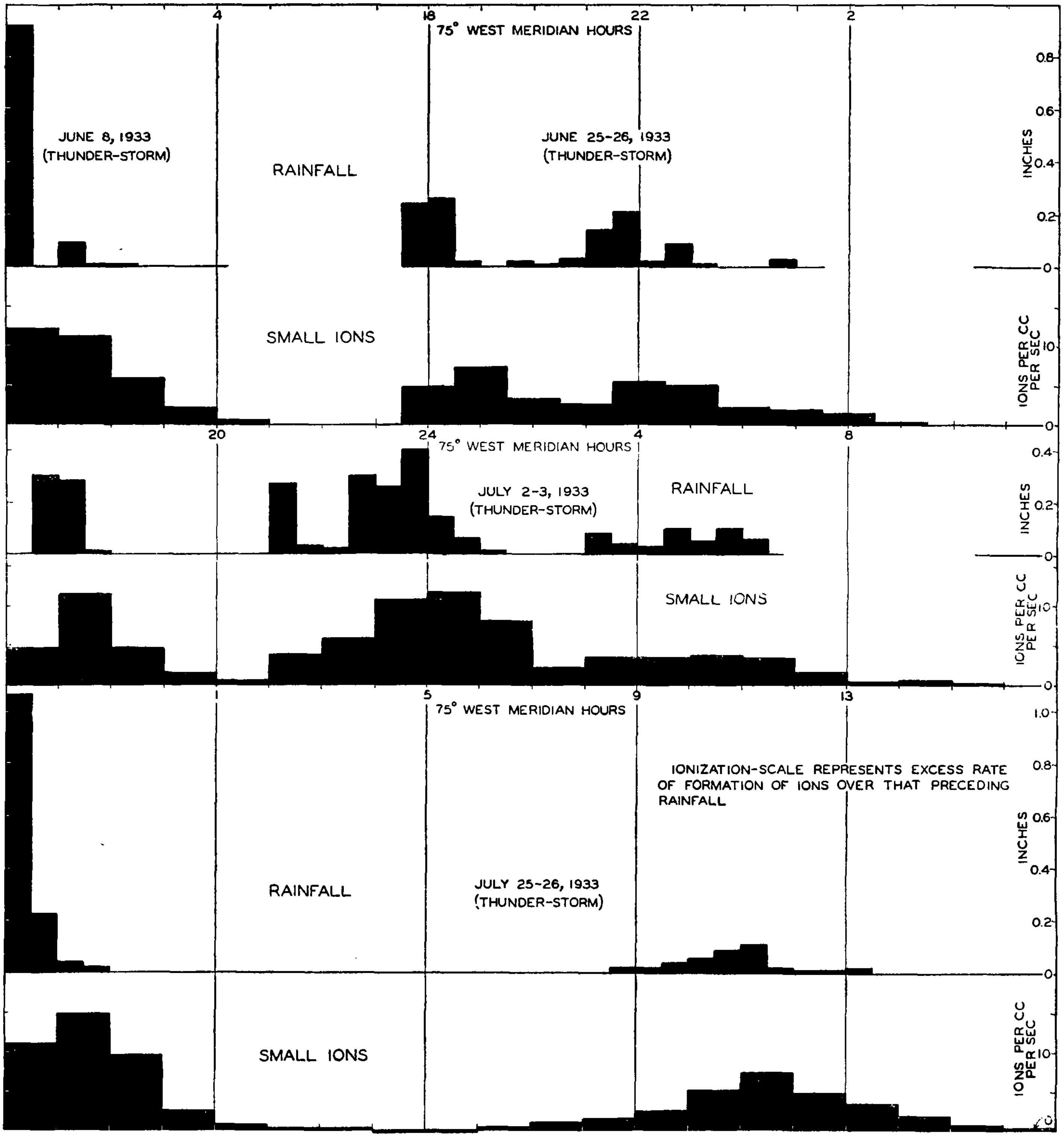

FIGURE 3a. Comparison rainfall and production small ions, Washington, D.C.

complications involved, such as run-off during intense showers and absorption of the rain by the ground.

The decay of the rate of ion formation after the rain has ceased for the several heavier showers is represented by figure 5. A curve of the equation $I=I_0e^{-\lambda t}$ fitted to the data by least squares gives a value of 1.088 per hour for λ. A curve drawn for $\lambda=1.548$ per hour, which is the constant for radium *B*, fits the data quite as well as might be expected in view of the statistical fluctuations involved.

Apparently the explanation of this phenomenon is that the decay products of radium, principally radium *B* and

C in equilibrium with it, are carried to earth with the rain and in their disintegration produce the ionization. Radium emanation, if it is present in the falling rain, does not contribute to the ionization within the chamber, nor does it control the rate of decay of radium *B* and radium *C* present, to any appreciable extent, as evidenced by the rapidity of the decay, since the half-period for radium emanation is nearly 4 days. This cannot be adduced as proof of the absence of appreciable quantities of radium emanation in rain because radium emanation if carried by the rain might be quickly dissipated upon evaporation or absorption of the rain. Furthermore, although radium emanation is a powerful producer of ions, it would not produce many in the ionization chamber because it gives off only alpha particles which would not penetrate the walls of the chamber unless the disintegration which gives rise to them occurs within a few centimeters of the chamber, and then only a short portion of their effective paths would be inside the chamber.

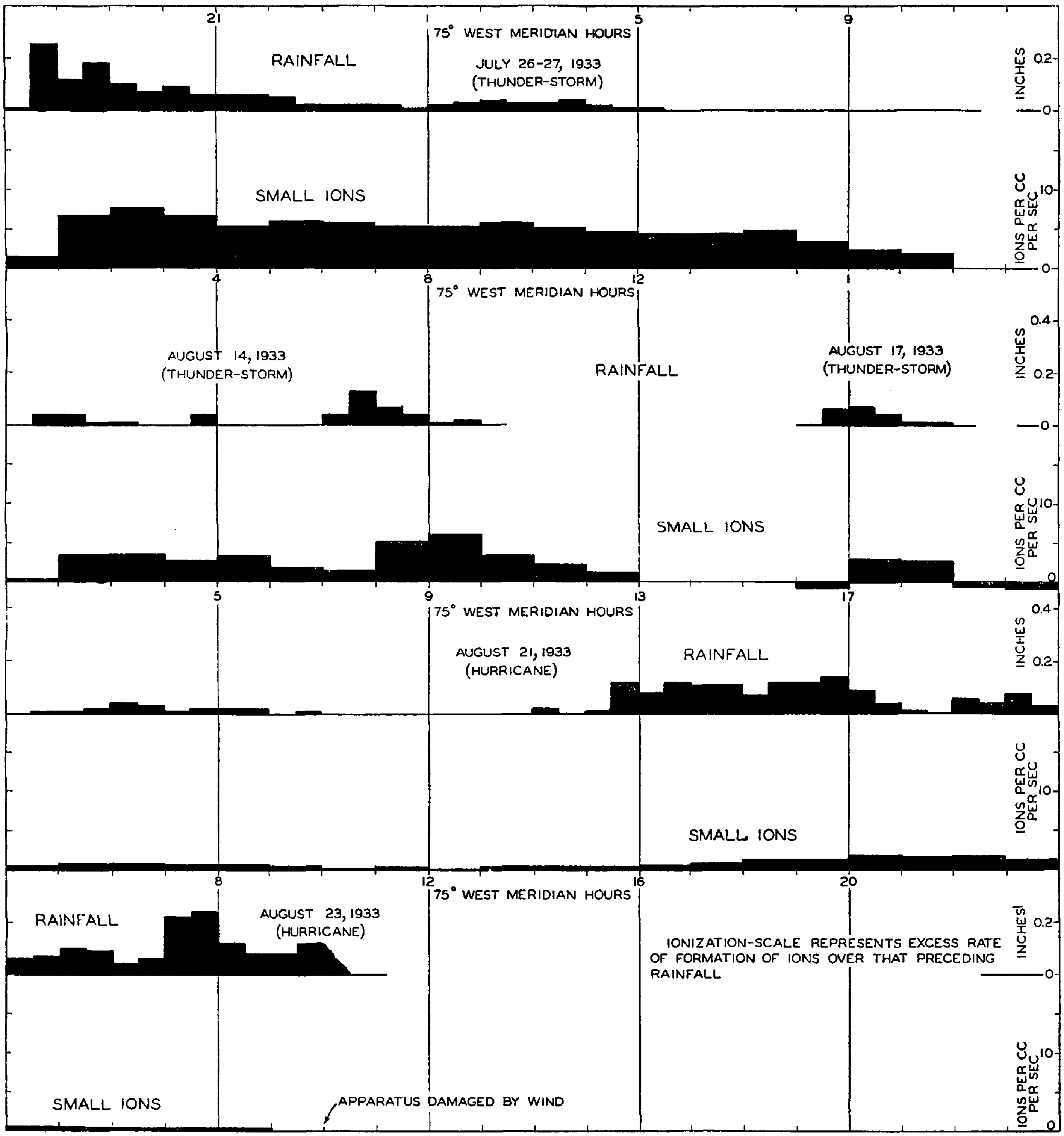

FIGURE 3*b*. Comparison rainfall and production small ions, Washington, D.C.

Although the presence of radioactive substances in precipitation has long been known through the radioactivity of the residue left after evaporation,[1] the observations cited above yield an interesting insight into the problem. Undoubtedly radium emanation, escaping from the soil, is carried up into the air. There it may be dissolved in existing cloud droplets, immediately after which disintegration would take place producing radium *A*, *B*, and *C*; or cloud droplets may be formed on atoms of radium *A*, *B*, and *C* (produced in the air by the emanation) if, as is doubtful, these act as condensation nuclei. In either case, an explanation of the absence of the ionizing agent in the hurricane rain previously referred to becomes necessary. Two causes are probably operative: (*a*) The rain which falls in a hurricane proceeds from a layer of air which has long been out of contact with the earth's surface and consequently any short-lived radioactive matter in it has had sufficient time to decay, whereas the rain from a thundercloud is falling from air which just a short time before—perhaps less than an hour—was in intimate contact with the earth's surface when the barometer was low and the emanation most likely to escape from the soil.

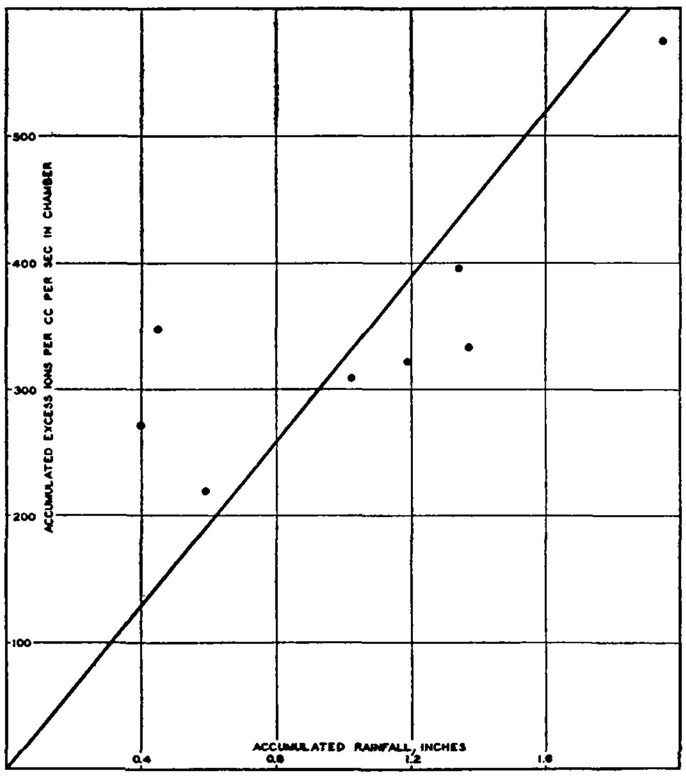

FIGURE 4.—Excess of ionization produced by thunderstorms.

(*b*) While the air which feeds moisture into a thundercloud over the land comes from the land, the rain-laden air of a hurricane comes from the ocean where the radioactive content of the atmosphere has been observed to be very low.

An interesting aspect of this phenomenon is that the increase of ion formation during a thunderstorm is several fold, a condition not shown by the investigations of the residue from evaporated rain referred to previously. This invites speculation as to its significance when considered in relation to the general study of atmospheric electricity. If the increase of ion formation during a thunderstorm is a quite general phenomenon over the land, a greater air-earth electric current should occur during a thunderstorm for the same potential gradient, thus lending weight to C. T. R. Wilson's theory[2] that the earth's electric charge is replenished by compensating currents flowing beneath thunderclouds, and consequently to a further suggestion as to the cause of the universal-time component of the diurnal variation of the earth's electrical potential gradient in accordance with Whipple's[3] extension of this theory.

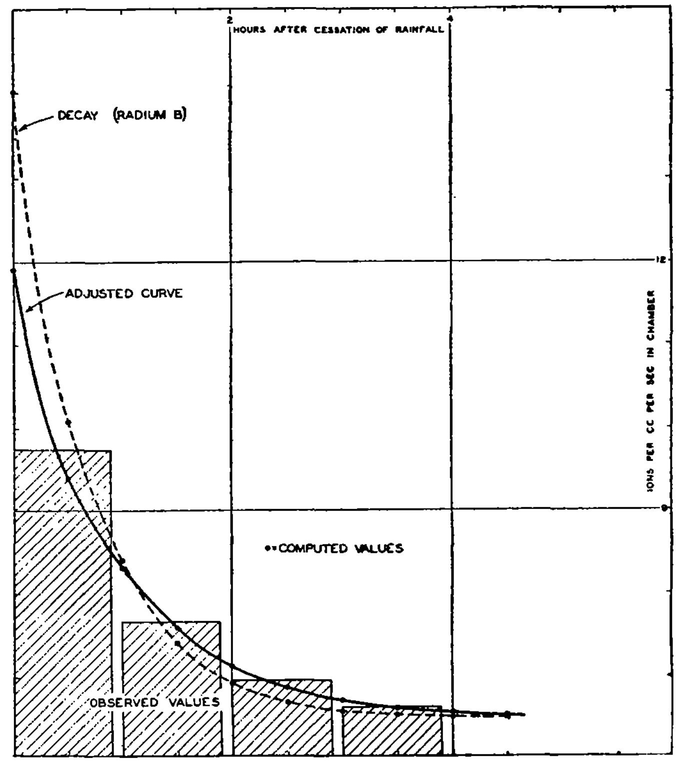

FIGURE 5.—Ionization decay following thundershower (mean 8 showers, Washington, D.C., summer 1933).

[1] V. F. Hess, The Electrical Conductivity of the Atmosphere and Its Gases, pp. 113–14, 1928.

[2] R. Glazebrook, A Dictionary of Applied Physics, 3, 100 (1923).

[3] Q. J. R. Met. Soc., 58, 301-302 (1932).